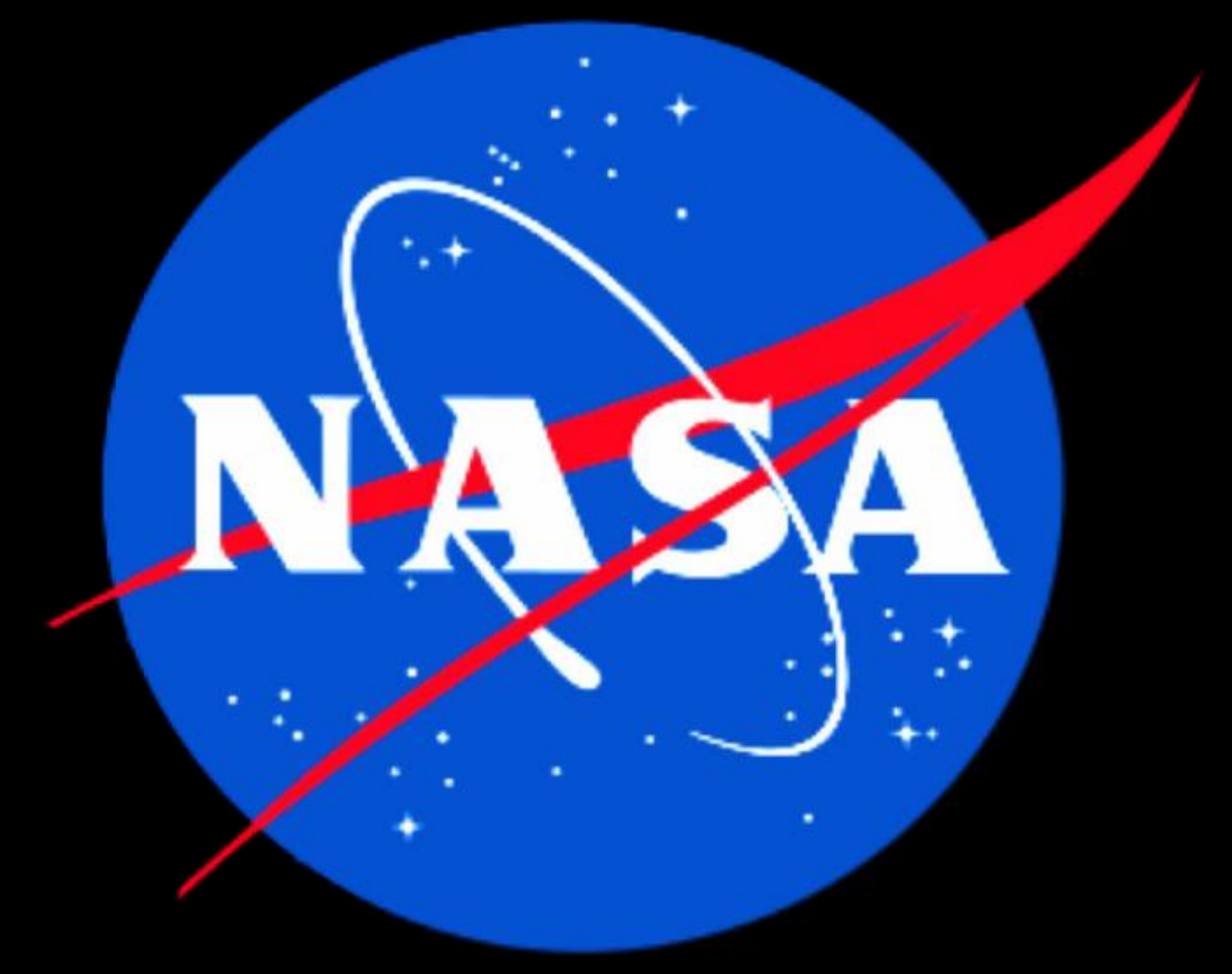


Composite Overwrap Fragmentation Observations, Concerns, and Recommendations



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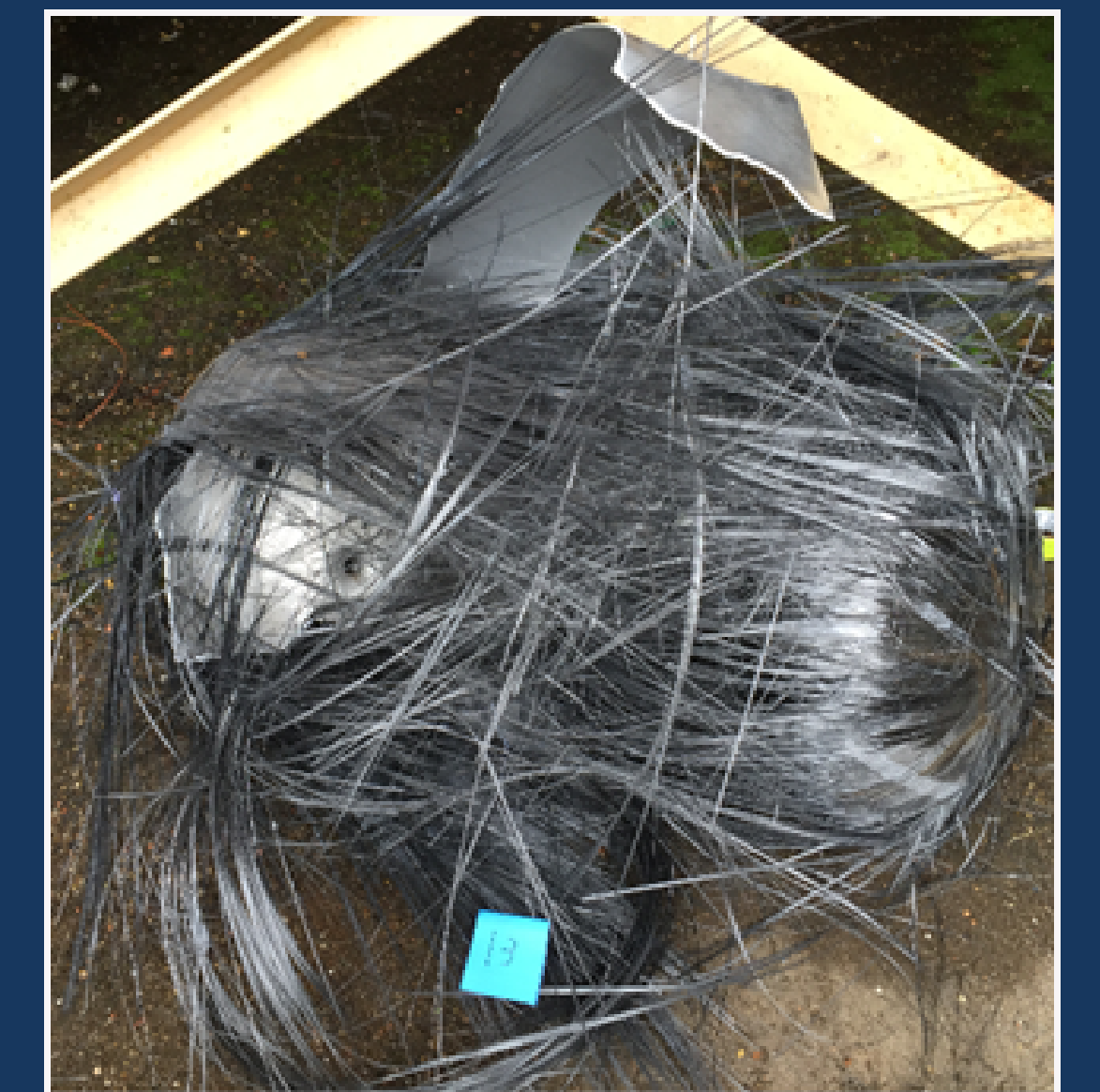
Observations

A series of test activities has raised some concerns about the generation of orbital debris caused by failures of composite over wrapped pressure vessels (COPVs). These tests have indicated that a large number of composite fragments can be produced by either pressure/burst failures or by high-speed impacts.



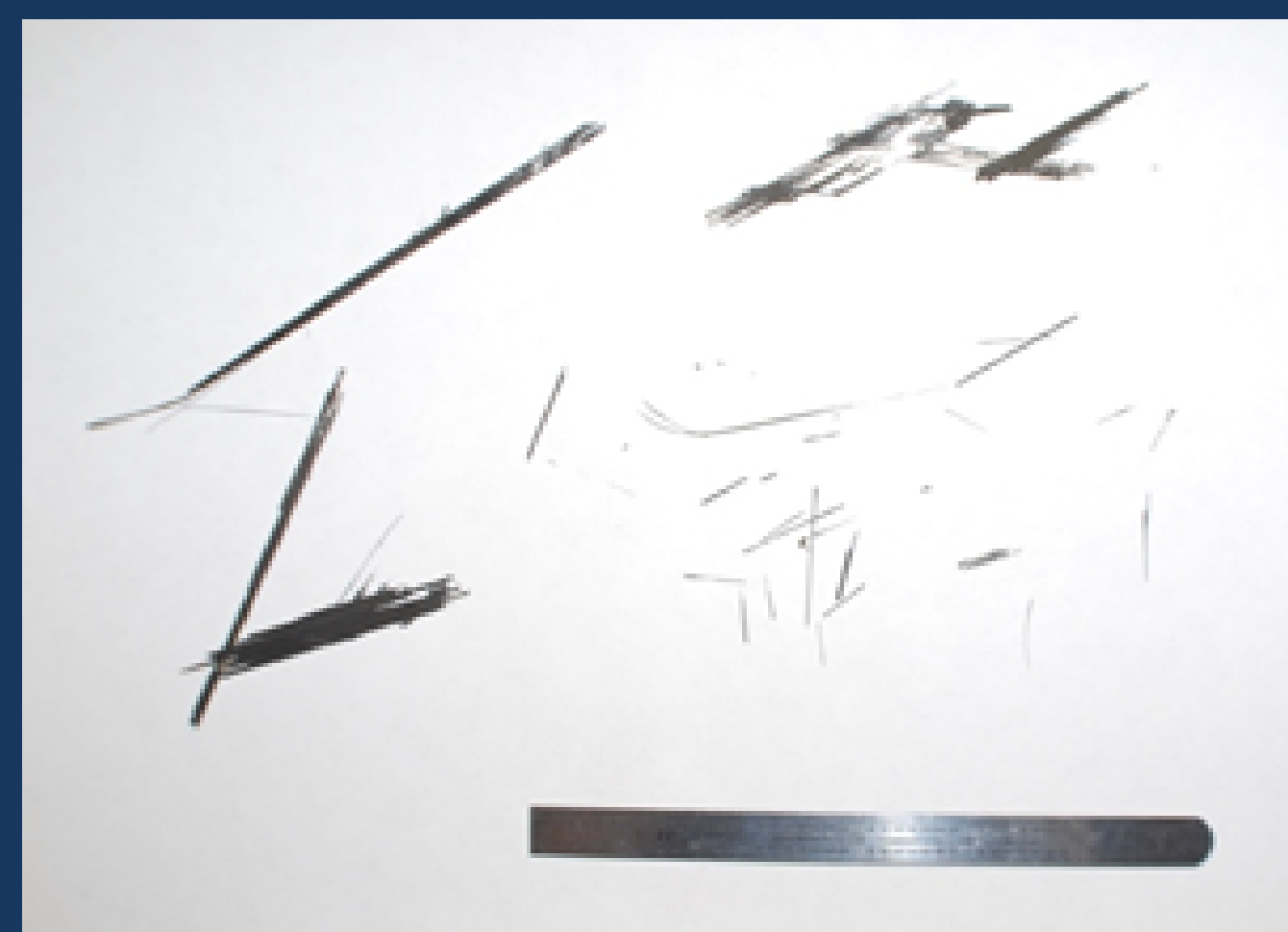
Photo courtesy of AEDC

A review of prior high-speed tests with COPV indicates that other tests have produced large numbers of composite fragments. As was the case with the test referenced here, the tests tended to produce a large number of small composite fragments with relatively low velocities induced by the impact and/or gas expansion.



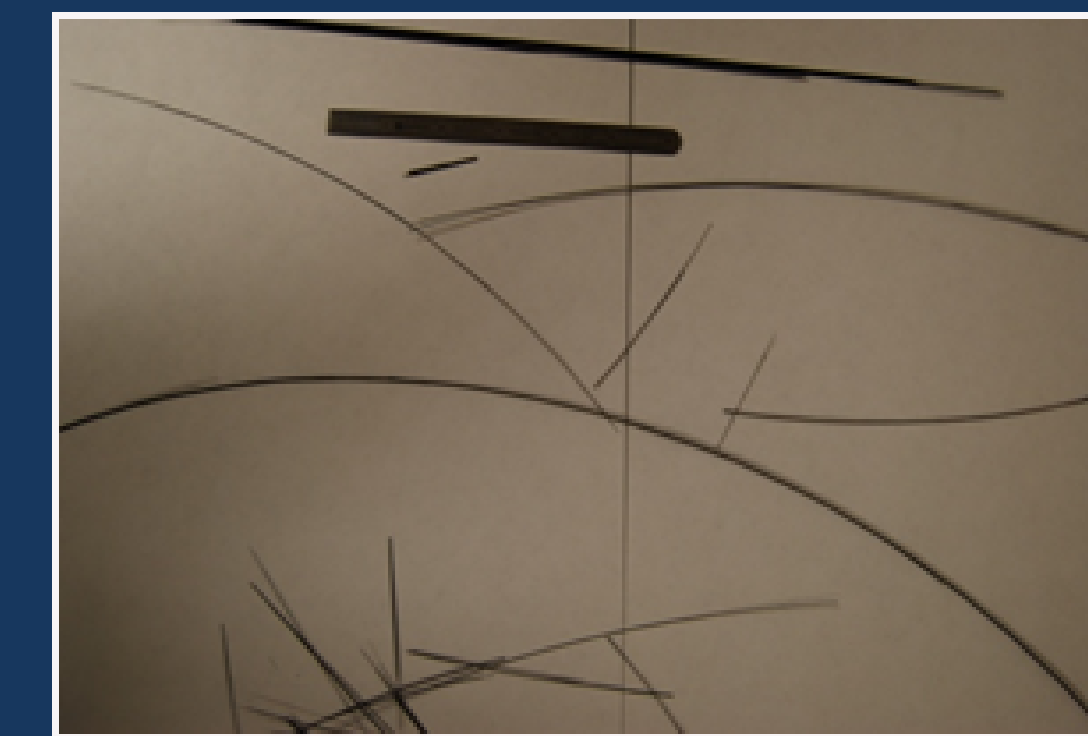
Bundles of composite fibers thrown from burst test.

Concerns



Large numbers of very small composite fragments were produced. The figures show fibers that remain attached and representative smaller fragments released with a 6-in ruler as reference.

The design of composite structures is a complex engineering challenge. The nature of the epoxies, fibers, and layups affect strength and mass, and may also affect debris generation. These variables may also affect the orbital debris produced so adjustments in the composites may allow designers the ability to reduce the potential for debris if the analysis so indicates.



Representative composite fragments produced from burst test: Large numbers of small fragments similar to these were produced. Those in photo on left are 3 to 6 inches long, and the photo on right shows fragments over 20 inches long. Fragments ranged from very small flakes to strands that are multiple feet long.

If damage area (surface or otherwise) is an issue then this may be a significant concern to sensitive surfaces including solar arrays, mirrors, or thermal coatings for clouds of composite fragments.

Recommendations

- Tests will provide benefits across multiple agencies and applications.
- Understanding the threat from the fragments that are produced will allow the MMOD team to provide better risk assessments.
- Near field data will provide human spaceflight needed data on how to mitigate the risk from these failures either from thermal runaways or from high-speed impacts.
- Data could be used to improve future satellite designs to minimize debris sources.
- Knowledge of composite failures under either high-speed impacts or from burst events can lead to better/safer designs of the composite overwraps, as well as other composite structures, to minimize future debris risk.
- Observations from tests that were not designed to assess debris generation can lead to incorrect conclusions, but ignoring the obvious trends that these are indicating would appear to be ill-advised.

- Initial testing is recommended to be performed to identify the existence of real risk.
- A multistep process is anticipated, with the first step being to identify potential risk from the composite debris being produced.
- The steps consist of four test series with a parallel analysis to be done by the appropriate MMOD experts.

- 1) Conduct an abbreviated test series to assess potential for serious damage from these lightweight composite fragments. The recommended first step is the use of the Micro Light Gas Gun (MLGG) with velocities representative of orbital impact velocities. Composite samples are available and the team has begun to examine mechanisms to accelerate these small projectiles to the required velocities. Sabot materials are available and some experiments have been made to assess approaches to containing the fragments in question without interfering with the impacts. There is some urgency in step 1 in that the use of composite structures, covers, and COPVs are accelerating in launch vehicles upper stages, spacecraft, CubeSats, etc.
- 2) If step 1 indicates there is meaningful threat to on-orbit systems then, based on results obtained, develop a formal test series for composite fragments that addresses composition, velocities, angle of impact, etc.
- 3) Extend the test series from the failure of COPV configurations to all representative composite structures/materials to assess the generation of the composite fragments.
- 4) Add witness plates to the current NASA Engineering and Safety Center study of COPV failures from high-speed impacts to examine the effects of catastrophic COPV failures on surrounding areas that would be similar to Space Launch System (SLS).